MICRO-IRRIGATION MANAGEMENT FOR VEGETABLES IN A HUMID AREA

by

C. R. Camp, Agricultural Engineer, USDA-ARS
J. T. Garrett, Horticulturist, Clemson University
W. J. Busscher, Soil Scientist, USDA-ARS
E. J. Sadler, Soil Scientist, USDA-ARS

Florence, South Carolina 29502-3039

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SUMMARY:

Two surface and one subsurface micro-irrigation treatments and two application frequencies were evaluated for five vegetable crops. Yields were acceptable to outstanding, ~~except for muskmelon~~, delete and there was little yield differences among treatments. One treatment used about half as much irrigation water.

KEYWORDS:
Trickle irrigation, squash, green bean, muskmelon, cowpea, broccoli, subsurface irrigation.

INTRODUCTION

Micro irrigation offers several advantages, including precise water placement, low water pressure, and low water delivery rate. In most cases, tubing and some system components are replaced annually, limiting micro irrigation application to high-value crops. Practices or designs which would either reduce the number of replaceable components or prolong their use beyond a single season would make this technology profitable for lesser-valued crops. On a coarse-textured soil in Arizona, cotton yields were comparable for tubes placed every row (1-m spacing) and every other row (2-m spacing) but were much lower for tubes placed every third row (3-m spacing) (French et al., 1985). Micro-irrigation tubing installed 0.2-0.3 m below the soil surface to allow shallow tillage and cultivation has been used successfully for fruits and vegetables (Bucks et al., 1981), potato (Sammis, 1980), tomato (Phene et al., 1983), cotton (Tollefson, 1985; Plaut et al., 1985) and corn (Camp et al., 1989). If preventive maintenance methods to prevent or reduce root penetration and plugging of emitters can be developed, this design should allow continued use of the system for several years without tubing replacement.

Seasonal rainfall amounts in the southeastern Coastal Plain are often adequate to satisfy crop water requirements, but yield-reducing periods of water stress occur most years. This is caused by the combination of low water storage capacity of the coarse-textured soils and short drought periods (5-20 days). Water storage available for plant extraction is further reduced by compacted soil layers that restrict crop rooting to relatively shallow depth. Consequently, during drought periods, irrigation is needed to produce crops of consistent high quality and high yield. Other types of irrigation can alleviate some of these problems and increase crop income most years, but energy and equipment costs and low commodity prices reduce profitability.

Annual in-row subsoiling during planting is often used to disrupt compacted layers and allow deeper root growth in Coastal Plain soils (Busscher et al., 1986). Improved root growth also occurs in these soils when the water content is between saturation and the upper limit of plant-available water (Campbell et al., 1974). Consequently, micro-irrigation tubes located near the top of a compacted layer and operated at a high frequency could maintain the compacted soil in a low-resistance state, promote improved root growth, and reduce the need for subsoiling.

Micro-irrigation systems had been installed in 1984 and had been used to evaluate six micro-irrigation treatments for corn in a coarse-textured soil of the southeastern Coastal Plain during 1985-1987 (Camp et al., 1989). These same systems were used to evaluate six micro-irrigation treatments for five vegetable crops during the spring and fall growing seasons in 1988 and 1989. Objectives of this study were (1) to determine the effect of tubing placement and irrigation frequency on growth and yield of five vegetable crops, (2) to determine the feasibility of double-cropping vegetable crops using the same irrigation equipment, (3) to estimate crop water requirements for five vegetable crops under micro irrigation, and (4) to evaluate the longevity of buried micro-irrigation tubing.

MATERIALS AND METHODS

Vegetables were grown on raised beds spaced 1.5 m apart on a 0.20-ha site of Norfolk loamy sand near Florence, South Carolina, for a two-year period (1988-89). The E soil horizon was not clearly defined and appeared to be mixed with the Ap horizon to a depth of 0.3 m, probably because of antecedent deep tillage. Each of 48 experimental plots had two beds 12 m long, each bed with either a single row or two rows spaced about 0.50 m apart, depending upon crop. Irrigation was managed independently for each of the 48 plots. Each plot was split into two crop subplots, each 6 m long, but subplots could not be irrigated independently. Consequently, crops with anticipated similar water requirements were planted on the same bed, e.g. green bean-cowpea and squash-muskmelon (Fig. 1). Four vegetable crops (green bean, cowpea, squash, and muskmelon) were planted or transplanted in the spring each year, one crop on each irrigation treatment subplot. Broccoli was grown as a single crop in the fall each year. In 1988, plots were 12 m long, and in 1989, were 6 m long because of a limited supply of plants (Fig. 2). Crops were rotated within an irrigation treatment each year so that a crop was not grown on the same site each year. Plot areas harvested for each crop and year are shown in Table 1.

Six irrigation treatments were completely randomized in each of four blocks when the systems were installed in 1984. Treatments and crops were randomized each year subject to the restrictions of existing subsurface plots. Treatments consisted of all combinations of three micro-irrigation tubing locations and two application modes. Irrigation tubing locations were (1) two tubes buried 0.3 m under each bed, (2) two tubes on the surface on each bed, and (3) one tube on the surface on each bed (Fig. 3). Irrigation was applied through each system at either high or low frequencies. For the low-frequency treatments, irrigation was applied without interruption until the desired daily amount had been applied. For the high-frequency treatment, irrigation was applied in three equal pulses each day, one-third of the application amount every four hours.

The subsurface tubing had been installed in fall of 1984 at 0.3-m depth using a modified subsoiler shank and remained in the soil continuously. At this depth, the tubing was at the interface between the Ap and B horizons and was below the frost line. Surface tubing was installed each season after transplanting and/or planting and was removed after harvest. The same tubing was used continuously for five years in all treatments. Irrigation tubing (Lake Drip-In[1]) had in-line, labyrinth emitters spaced 0.6 m apart, each delivering 1.9 L/h. Each lateral was equipped with a removable end cap that was utilized for line flushing. All laterals within a plot were connected to a separate manifold where flow was controlled by a solenoid valve and pressure was regulated at about 100 kPa by individual, in-line pressure regulators.

Prior to installation of the subsurface irrigation system in 1984, the site was subsoiled in two directions (45° to the row direction and perpendicular to each other) and was disked until the surface was smooth. Thereafter, the only tillage used was disking and smoothing to remove weeds

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agr. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

and to incorporate chemicals, rotatilling to prepare for bed shaping, and shaping and compressing the beds. Pesticides were applied in accordance with South Carolina Cooperative Extension Service recommendations. In 1988, beds used for squash and muskmelon were injected with a methyl bromide-chloropicrin mixture at a depth of about 0.15 m using two shanks spaced about 0.5 m apart and then covered with plastic mulch. In 1989, the entire experimental area was treated with the methyl bromide-chloropicrin mixture and covered with plastic for 3 days. Beds were formed after removing the plastic sheet and the squash and muskmelon beds were again covered with plastic mulch. Fertilizer P and K requirements were determined by soil test each year. Preplant fertilizer and liquid herbicide were broadcast and incorporated. Additional fertilizer nutrients were added through the irrigation system or as granules on the surface at various intervals depending upon the particular crop. Fertilizer applications, planting and harvesting dates, and crop varieties for all crops are shown in Table 1 for both years. Squash and muskmelon yields were determined for each grade according to industry grading standards. Sieve analyses and shell-out percentages were determined from yield subsamples for green bean and cowpea, respectively. Broccoli yields were determined for market-standard stalk length and grade.

The chlorinated irrigation water supply was filtered using a 100-mesh cartridge filter. The system was flushed at the beginning of each growing season and periodically during the growing season to remove any sediment or residue that might cause emitter plugging. At the end of each growing season, a higher-concentration chlorine solution was injected into the system to reduce biological activity and to retard root entry into emitters. The system was also treated with sulfuric acid and a higher concentration chlorine solution in spring, 1989, before the spring growing season. Sulfuric acid (10%) and sodium hypochlorite (5.25%) solutions were injected into the irrigation system for sufficient time to provide a pH of 2 and a chlorine concentration of 10 ppm throughout the system. Irrigation and injection were terminated and the solution was allowed to remain in the system for about 12 h before removing end caps and flushing with water.

Tensiometers were installed at depths of 0.3 and 0.45 m midway between double rows or within single rows in each subplot (one set for each crop) in two blocks for the spring crops. Tensiometers in broccoli plots were installed at depths of 0.15 m and 0.30 m. Tensiometer readings were recorded three times each week and tensiometers were serviced at least once each week. Rainfall was measured on site with a tipping-bucket rain gauge. A programmable irrigation controller monitored and controlled all irrigation applications. Water volume applied to each pair of blocks was also measured with indicating flow meters. Irrigation was applied when the tensiometers at the 0.3-m depth (0.15-m depth for broccoli) in the double-tube treatments reached 30 kPa. In most cases, an irrigation application of 6 mm was applied to all double-tube treatments; one-half of this amount was applied to single-tube treatments. Equal water volumes were applied to high- and low-frequency treatments. All yields were analyzed using analysis of variance and least squares difference procedures. Each crop was analyzed as an independent experiment. Differences among treatment means at the $P \leq .05$ level are reported only if the F-test in ANOVA procedure indicated significant treatment differences.

RESULTS AND DISCUSSION

Seasonal rainfall and irrigation amounts for all treatments, crop, and years are included in Table 2. Generally, rainfall was lower in 1988 than in 1989 although the opposite was true for squash and broccoli. There was also significant variation in rainfall amount among various crop seasons within each year. Similarly, irrigation amounts varied considerably among crops and between the two years, but were generally higher in 1988 when rainfall amounts were generally lower; however, there were exceptions to this general trend also. Irrigation amounts for the 1-tube treatments were about one-half those for the 2-tube treatments because all systems were operated for equal time periods. Minor exceptions occurred in 1989 because of significant sprinkler irrigation to enhance seed germination and to establish transplants.

Yield results for all five crops and both years are included in Table 3. There was no significance difference among cowpea yields for irrigation treatments in 1988 and yields were slightly higher in 1989. In 1989, the Surface, 1-tube treatment yield was significantly higher than the Surface, 2-tube yield at high irrigation frequency, and the Subsurface, 2-tube treatment had higher yield than the Surface, 2 tube treatment. Cowpea yields were higher than an acceptable industry yield both years. There was no difference among green bean yields in 1988 for irrigation treatments and yields were higher than industry standards both years. An acceptable industry yield for both cowpea and green bean is about 4 Mg/ha (Lorenz and Maynard, 1980). In 1989, the Surface, 2-tube yield was higher than other yields for high irrigation frequency, but was significantly higher than only the Surface, 1-tube yield at low frequency. Generally, there appears to be no difference between the high and low irrigation frequencies for cowpea and green bean.

There was no significant difference in muskmelon yield either year and all yields ~~were lower than an~~ higher acceptable industry yield of 15 Mg/ha (Lorenz and Maynard, 1980). There appears to be a trend towards higher yield for the low frequency application in 1989, particularly for the Subsurface, 2-tube and Surface, 1-tube irrigation treatments, but these differences were not significant. Although there were twice as many harvests in 1989, yields were only slightly higher the second year~~s~~. Similarly, there was no significant difference among squash yields (grades 1 and 2, combined) for various irrigation treatments either year, and all yields were exceptionally high. An acceptable industry yield for squash is 28 Mg/ha (Lorenz and Maynard, 1980). Yields in 1989 were almost double those in 1988, primarily because of an extended harvest period (50% more harvests) which resulted from a lower incidence of disease and good water, pest, and nutrient management.

Broccoli yields were similar for both years and there was no yield difference among treatments either year. Yields were slightly lower than yields expected by industry. The major problem encountered when producing this crop in the fall was establishing plants during the hot, dry weather normally experienced during August in the southeastern Coastal Plain. Availability of quality transplants was also a problem, even when we attempted to provide our own transplants in the greenhouse. Sprinkler irrigation was used, particularly in 1989, to establish transplants. Micro irrigation, especially tubing as used here, often does not wet an area large enough to support small root systems during critical periods, such as immediately following transplanting.

Generally, there was little difference in crop yield among the various irrigation treatments, but there was a difference in the amount of irrigation water applied during the season. The Surface, 1-tube treatment received about one half as much irrigation water as the 2-tube treatments, yet produced approximately the same yield. Part of the reason for this is the placement of the irrigation source nearer the single rows (squash and muskmelons) and midway between double rows (cowpea and green bean), and middle of the bed in both cases, which usually resulted in less runoff, even when the bed was covered with plastic. Water was observed running from under the plastic mulch into middles in several cases, even in the subsurface tubing treatment. In the subsurface treatment, water often moved to the soil surface or edge of the bed very soon after irrigation commenced. The final result may have been more efficient use of irrigation water in the single tube treatment, primarily because of better placement. Field observations of apparently better plant growth on the 1-tube treatment, particularly for squash and muskmelon, during various growth periods support this hypothesis.

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Acceptable to outstanding yield results were obtained for all crops ~~except muskmelon~~ and for all irrigation treatments, demonstrating the feasibility of this type of production system for the southeastern Coastal Plain. The subsurface micro-irrigation system performed well although it had been buried for a total of 5 years by the end of this experiment. Limited evaluation of the system indicates minimal problems with emitter plugging. Extensive evaluation of emitter plugging will be conducted later, but will probably involve destructive methods after termination of useful system life. Double cropping of vegetables, such as broccoli following one of the spring crops, was successfully demonstrated, using the same irrigation system for both crops and for both years of this experiment. With the three years these irrigation systems had been used in a previous experiment, a total useful life of at least five years was demonstrated.

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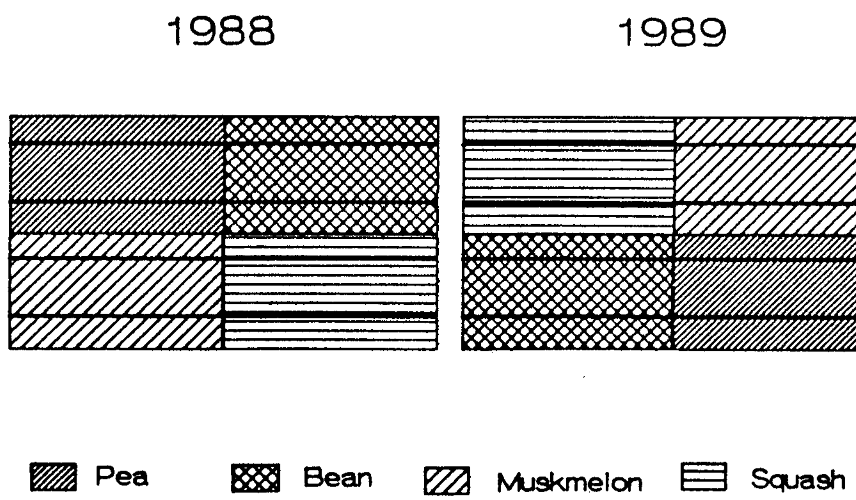

Figure 1. Crop rotation on two adjacent plots for four spring vegetable crops in a micro-irrigation experiment on a southeastern Coastal Plain soil during 1988-1989.

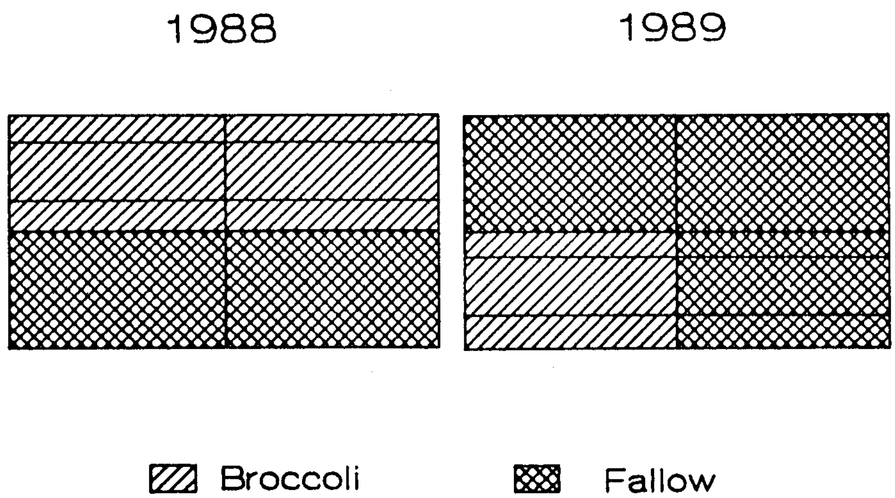

Figure 2. Crop rotation on two adjacent plots for broccoli grown in the fall in a micro-irrigation experiment on a southeastern Coastal Plain soil during 1988-1989.

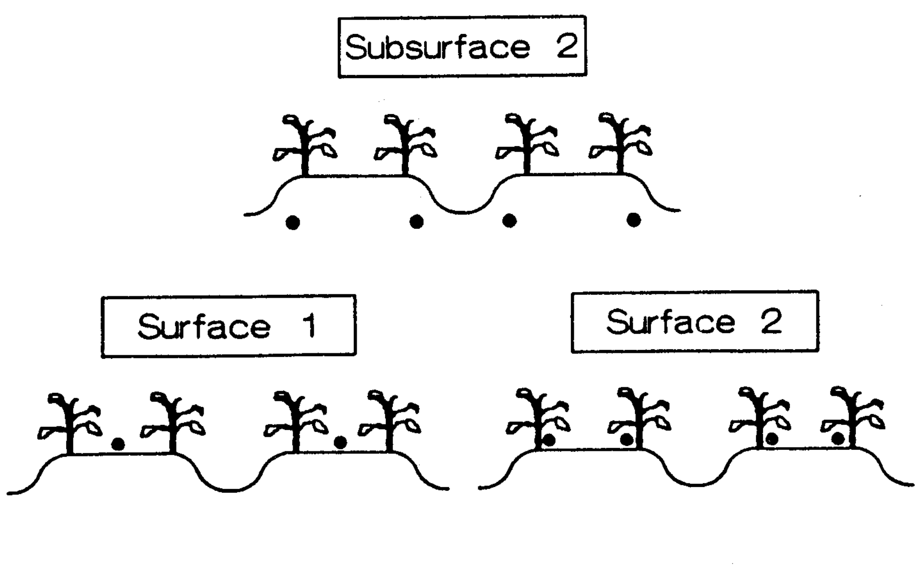

Figure 3. Schematic diagram of three micro-irrigation tubing placements in an experiment on a southeastern Coastal Plain soil during 1988-1989. Solid circles indicate micro-irrigation tubing locations.

Table 1. Vegetable varieties, planting and harvesting dates, and fertilizer application for a micro-irrigation experiment on a southeastern Coastal Plain soil during 1988-1989.

Year/Crop	Crop Variety	Planting Date	Last Harvest Date	Harvested Area	Fertilizer Preplant N	P	K	Sidedress** N	K	S
				---m---	---------kg/ha------------					
1988										
Cowpea	Magnolia Blackeye	Apr 26	Jul 29 (4)*	9.3	34	29	56	22	--	--
Green Bean	Blue Lake 274	Apr 28	Jul 1 (3)	9.3	34	29	56	22	--	--
Muskmelon	Mainstream	May 20	Jul 29 (7)	18.6	34	29	56	78(2)	--	5
Squash	Pavo	May 20	Aug 15 (15)	18.6	34	29	56	78(2)	--	5
Broccoli	Green Comet	Sep 14	Nov 30 (6)	37.2	42	36	70	104(3)	--	8
1989										
Cowpea	Mississippi Silver	May 31	Aug 15 (2)	9.3	34	29	56	34	34	--
Green Bean	Blue Lake 274	May 31	Aug 7 (3)	9.3	34	29	56	34	34	--
Muskmelon	Magnum 45	May 4	Aug 2 (14)	18.6	34	29	56	34	34	--
Squash	Pavo	Apr 28	Jul 14 (23)	18.6	34	29	56	34	34	--
Broccoli	Early Dawn	Sep 12	Nov 16 (6)	13.9	84	36	70	109(2)	100(2)	--

*Numbers in parentheses reflect either number of harvests or number of sidedress fertilizer applications, if greater than one.

**All sidedress applications were injected through the irrigation system except for the first application for broccoli each year, which was applied to the soil surface as granular ammonium nitrate in 1988 and as 15-0-14 fertilizer in 1989.

Table 2. Seasonal rainfall and irrigation amounts for five vegetable crops on a southeastern Coastal Plain soil during 1988-1989.

Year/Source	Crop: Cowpea	Green Bean	Muskmelon	Squash	Broccoli
	------------------------mm------------------------				
1988					
Rainfall	304(26)*	150(16)	278(24)	262(19)	179(17)
Irrigation					
2 tube	267(43)	124(20)	267(43)	241(39)	50(15)
1 tube	133(43)	62(20)	133(43)	121(39)	25(15)
1989					
Rainfall	390(34)	332(30)	381(34)	220(26)	100(15)
Irrigation					
2 tube	149(24)	136(22)	224(36)	217(34)	133(20)
1 tube	82(24)	76(22)	122(36)	119(34)	69(20)

*Numbers in parentheses refer to the number of rainfall or irrigation events during the season.

Table 3. Yields for five vegetable crops, three micro-irrigation treatments and two irrigation application frequencies during 1988-1989.

Irrigation Treatment	1988 High*	1988 Low	1989 High	1989 Low
	Mg/ha			
Cowpea				
Subsurface, 2 tubes	4.4 a**	5.7 a	6.8 ab	6.9 ab
Surface, 2 tubes	4.0 a	4.6 a	6.4 b	5.4 c
Surface, 1 tube	4.7 a	4.8 a	7.5 a	6.2 bc
Green Bean				
Subsurface, 2 tubes	6.5 a	7.1 a	4.5 b	6.7 ab
Surface, 2 tubes	8.9 a	8.4 a	8.5 a	7.7 a
Surface, 1 tube	8.9 a	6.9 a	4.4 b	4.3 b
Muskmelon				
Subsurface, 2 tubes	47.3 a	48.5 a	49.2 a	56.0 a
Surface, 2 tubes	46.2 a	46.0 a	49.8 a	50.4 a
Surface, 1 tube	48.4 a	48.1 a	47.7 a	60.9 a
Squash				
Subsurface, 2 tubes	33.1 a	32.8 a	51.3 a	57.9 a
Surface, 2 tubes	36.1 a	35.3 a	52.1 a	52.2 a
Surface, 1 tube	39.5 a	37.1 a	50.1 a	50.8 a
Broccoli				
Subsurface, 2 tubes	7.1 a	7.0 a	7.0 a	8.3 a
Surface, 2 tubes	8.0 a	7.6 a	8.1 a	8.4 a
Surface, 1 tube	8.1 a	6.7 a	8.5 a	9.0 a

*Irrigation application frequency.
**Numbers followed by the same letter within a crop and year are not significantly different using analysis of variance and least significant differences at $P \leq .05$.